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FRACTURES FROM DEVONIAN SHALE OUTCROPS ALONG THE PINE MOUNTAIN THRUST

by

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Abstract

Fracture patterns in the Devonian shale exposed along the Pine Mountain Thrust show much greater complexity than the overlying units. However, the trends of fractures in the upper part of the Devonian shale are nearly those of the overlying units. The amount and complexity of fracturing reflects the degree of, and distance from, the basal detachment fault plain.

Two zones of movement were found within the shales. The major fault occurs at the base of the shale, and the shales adjacent to the thrust plain show the most deformation. However, a zone of lesser movement occurred in the upper part of the shale. The two zones of deformation may match the reported productive zones found in the Big Sandy shale gas field to the west.

Joints in the Grainger shales and Berea sandstone have trends similar to that of the upper part of the underlying shale, but they are less variable.

Jointing in the overlying Newman limestone along Pine Mountain is similar but slightly rotated from the underlying Grainger shales. The joint trends consist of a dominant set parallel to the Pine Mountain Fault; and a less dominant set, perpendicular to the thrust front.

Eventually the results of this study will be combined with those of cored wells and other surface studies to present an integrated regional analysis of Devonian shale farctures.

LIST OF FIGURES

Purpose

Natural gas in the Big Sandy field of eastern Kentucky produces from fractures within the Devonian shale. There are only two areas where one can study these shale fractures at the surface near this field. The Devonian shales crop out in central Kentucky along the Cincinnati Arch, and in eastern Kentucky, they crop out just above the Pine Mountain Thrust. A separate study will report on fractures in the shales along the eastern flank of the Arch (Long, in progress). This study reports on the nature and origin of fractures in the Devonian shale that crop out along the Pine Mountain Thrust.

We hope that thru the documentation of fracture patterns in adjacent outcrops, meaningful comparisons can eventually be made with the production of natural gas from the Big Sandy gas field.

Location and Geologic Setting

Pine Mountain is a linear feature about 125 miles long extending from just northeast of Elkhorn City, Kentucky, where it abuts against the Russel Fork fault, southwestward to near Jacksboro, Tennessee, where it abuts against the Jacksboro fault (see Figure 1). It was interpreted by Rich, 1934, and many others since as the surface expression of a major ramp of a detachment thrust in the Devonian shale, across more competent units, either to extend the surface or to an incompetent horizon in the Pennsylvanian clastics. The upper part of the ramp has since been eroded. The movement of the upper plate along the ramp has brought sediments of Devonian and Mississippian age to the surface. Presumably the stress that created the thrust also extended into the foreland in the area of the Big Sandy shale gas field. However, major movement was diverted by the ramp of the thrust at Pine Mountain so that extensive transpost did not occur under the Big Sandy shale gas field. However, if the stress and some minor movement did extend into the shales under the Big Sandy field, as suggested by Shumaker (1978), then the documentation of joints on the Pine Mountain may lead to insights concerning the fracture patterns and production in the Big Sandy shale gas field. For a more complete analysis and discussion of the geology of the area, readers are referred expecially to Harris (1970) and Harris and Milici (1977).

Method of Investigation

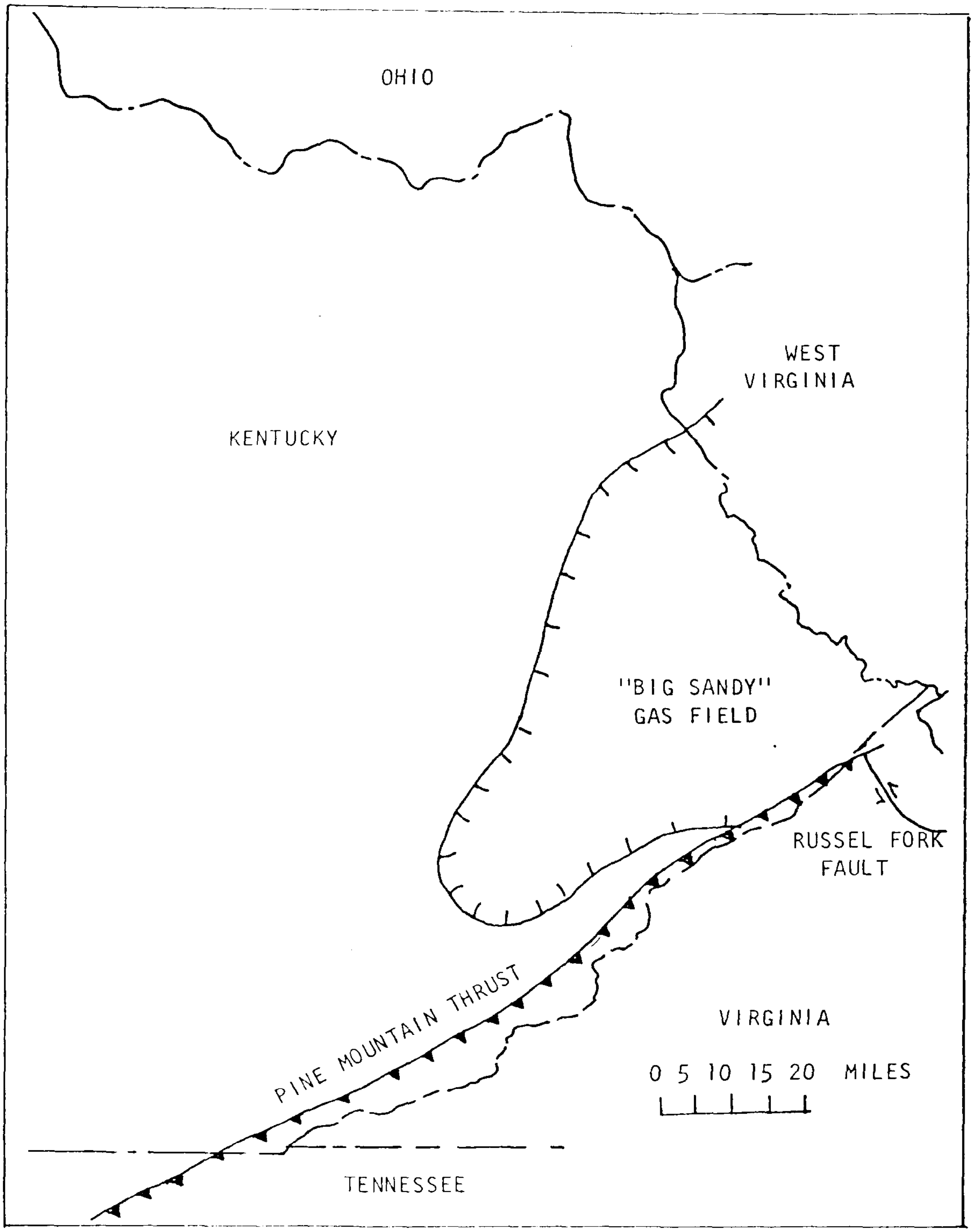
Field work was undertaken during July and August, 1978, to study fractures in the Devonian shales exposed along the base of Pine Mountain. Usually the shales are poorly exposed except in a few areas. The most complete exposures of the shale are along roads which cross the mountain or along quarry access roads to limestone which overlies the Devonian shale. Six exposures were found that were adequate to provide sufficient data for analyses of joints and outcrop-scale structures (Figures 4).

Except for the shale outcrop KL6 in the Bledsoe Quad, all exposures were moderately to intensely weathered.

Only joint sets that were consistant and repetitious throughout the outcrop were measured. Those joints judged to be random or unrepresentative of the dominant directions in the outcrop were noted, but not measured.

FIGURE 1

LOCATION MAP



Modified from Ray, 1976

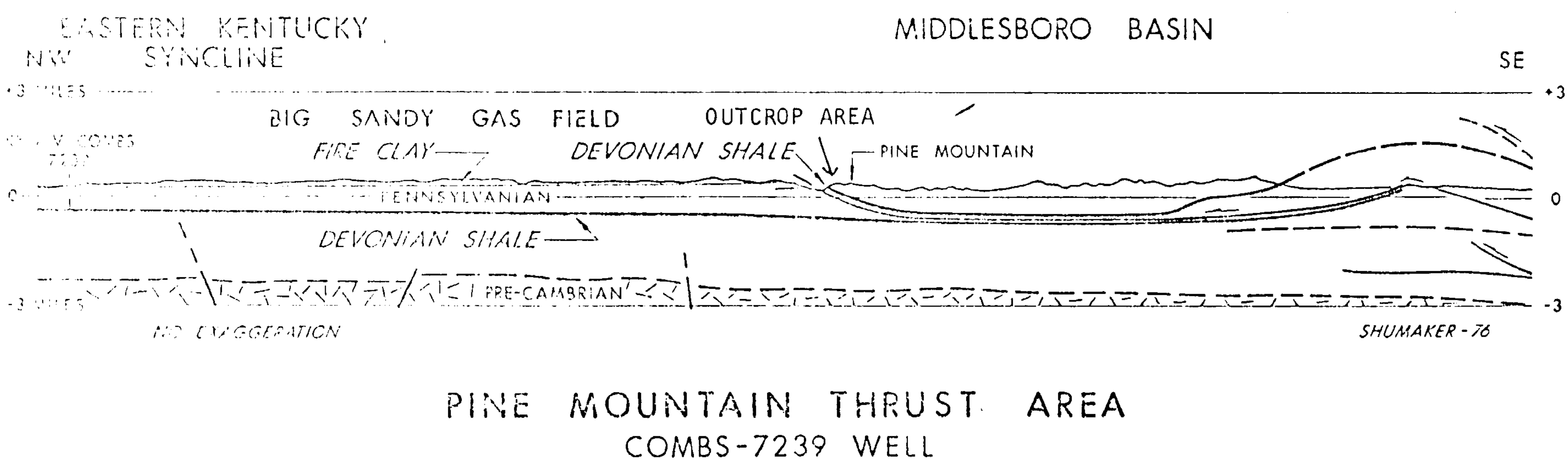


FIGURE 2
CROSS-SECTION-BIG SANDY GAS FIELD-
PINE MOUNTAIN THRUST

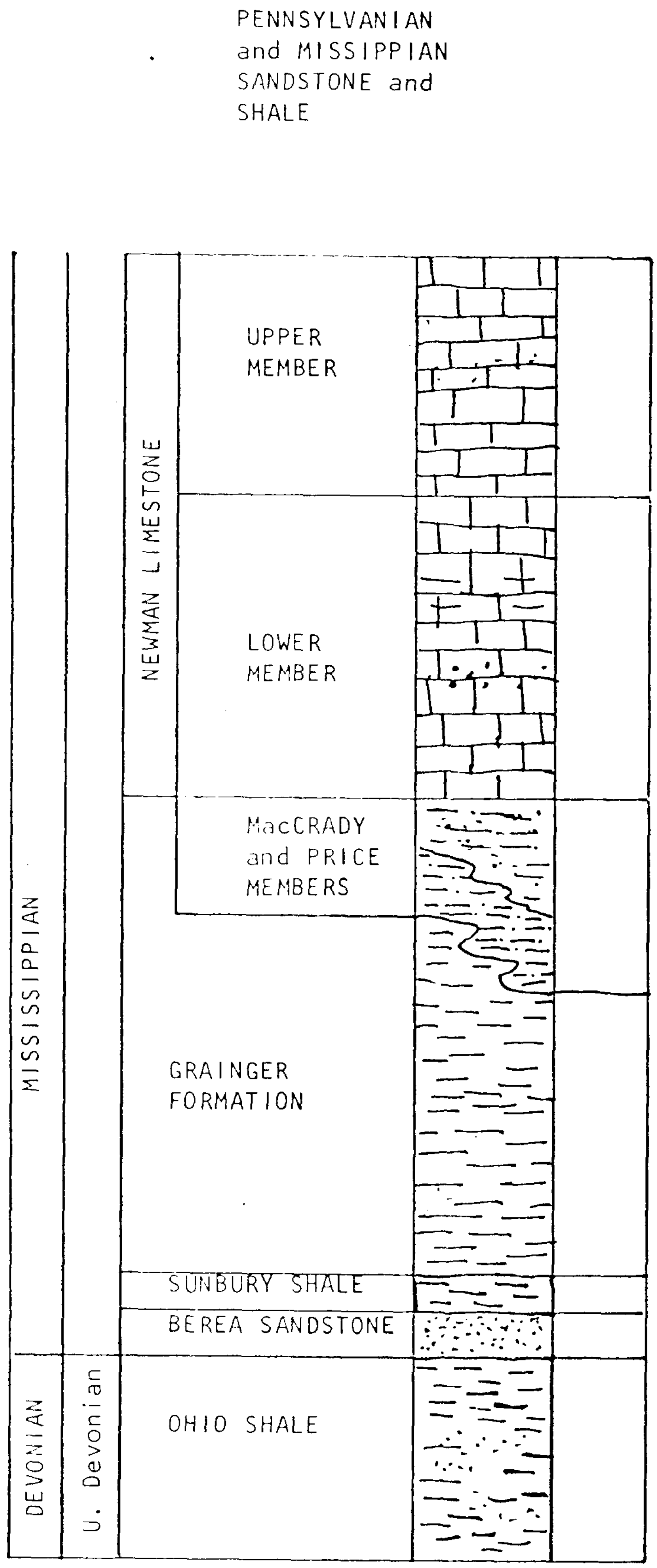


FIGURE 3
GENERAL STRATIGRAPHIC COLUMN

INDEX

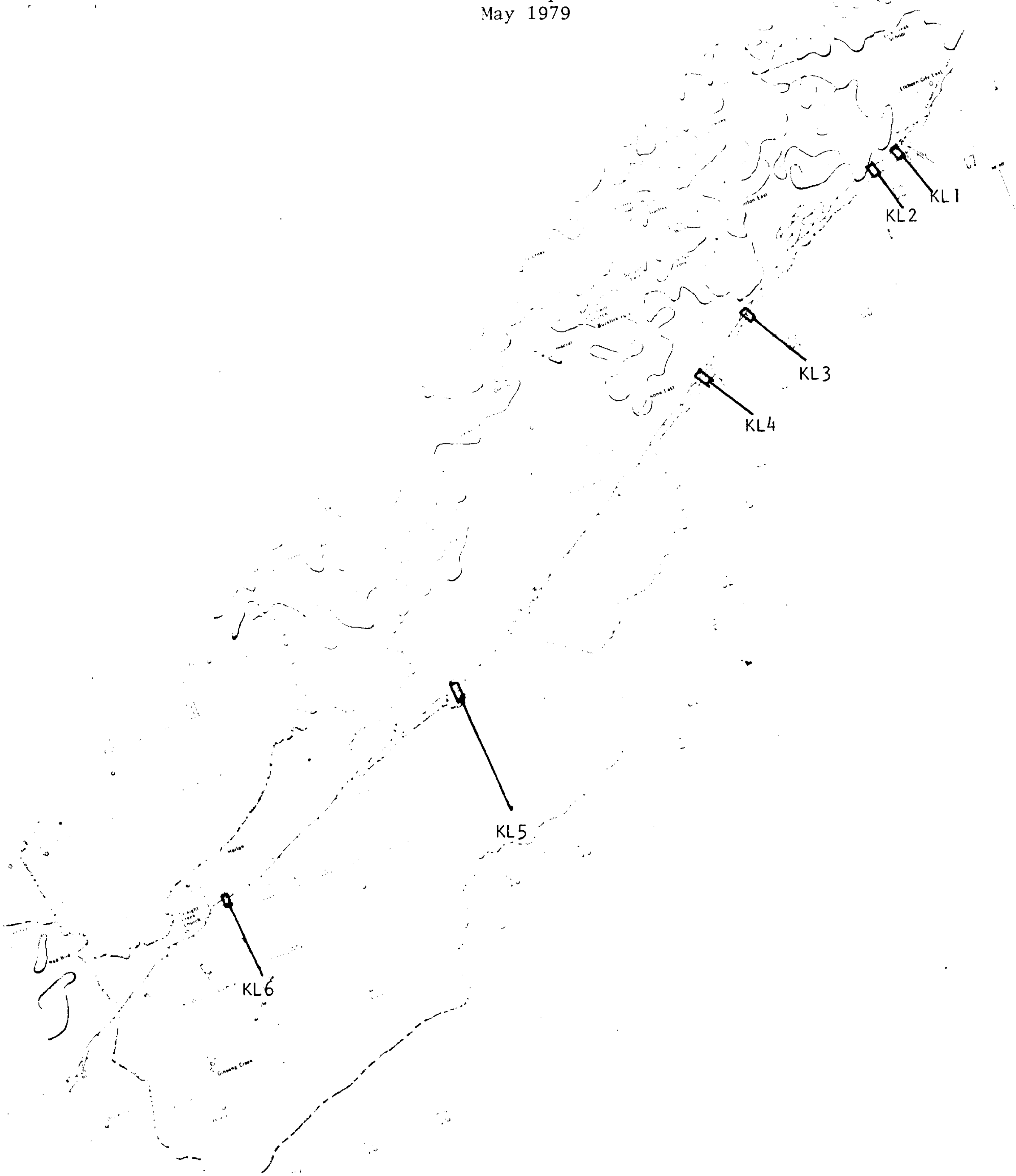


FIGURE 4
OUTCROP LOCATIONS

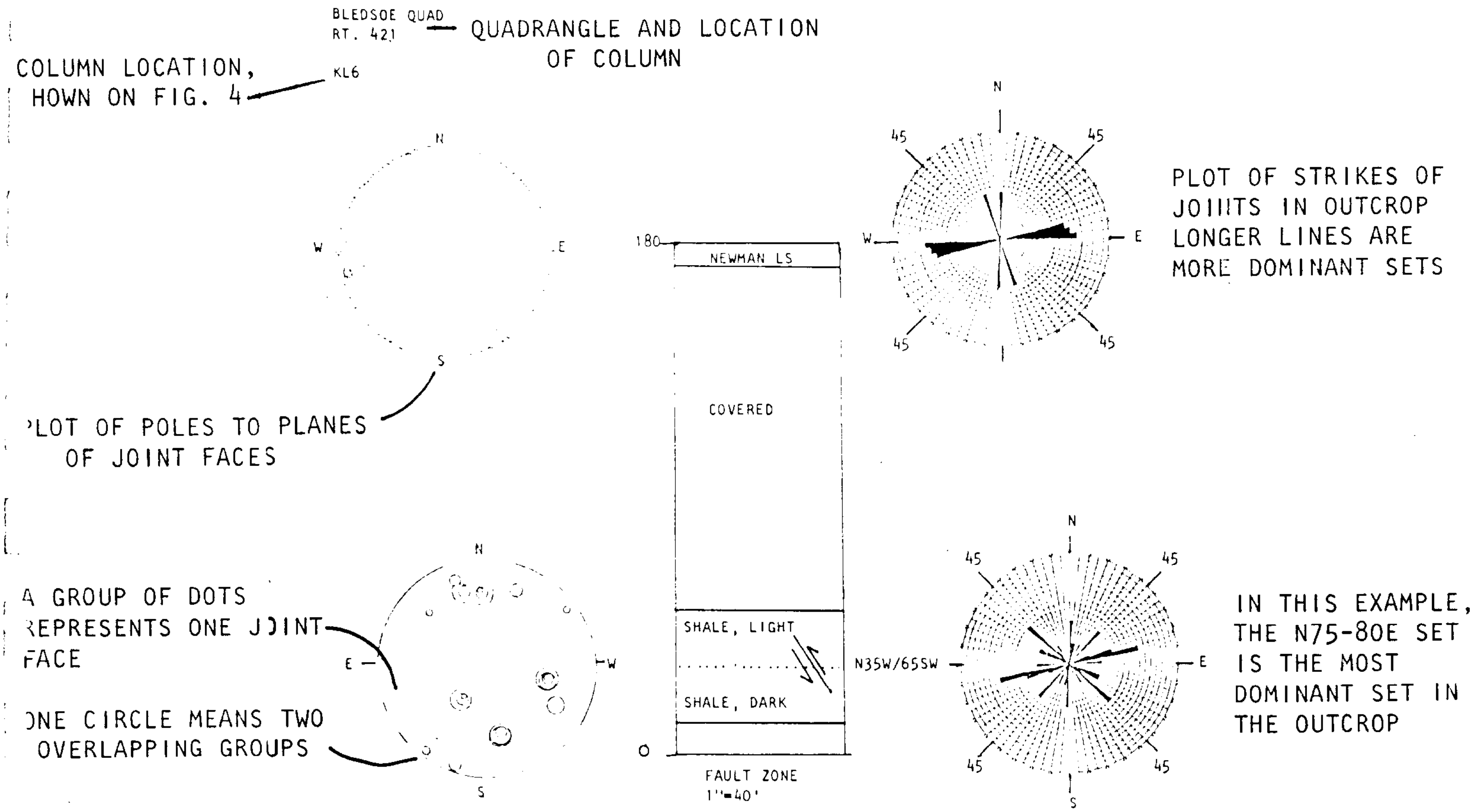


FIGURE 5
KEY TO COLUMNAR SECTIONS -
GUIDE TO INTERPRETATION

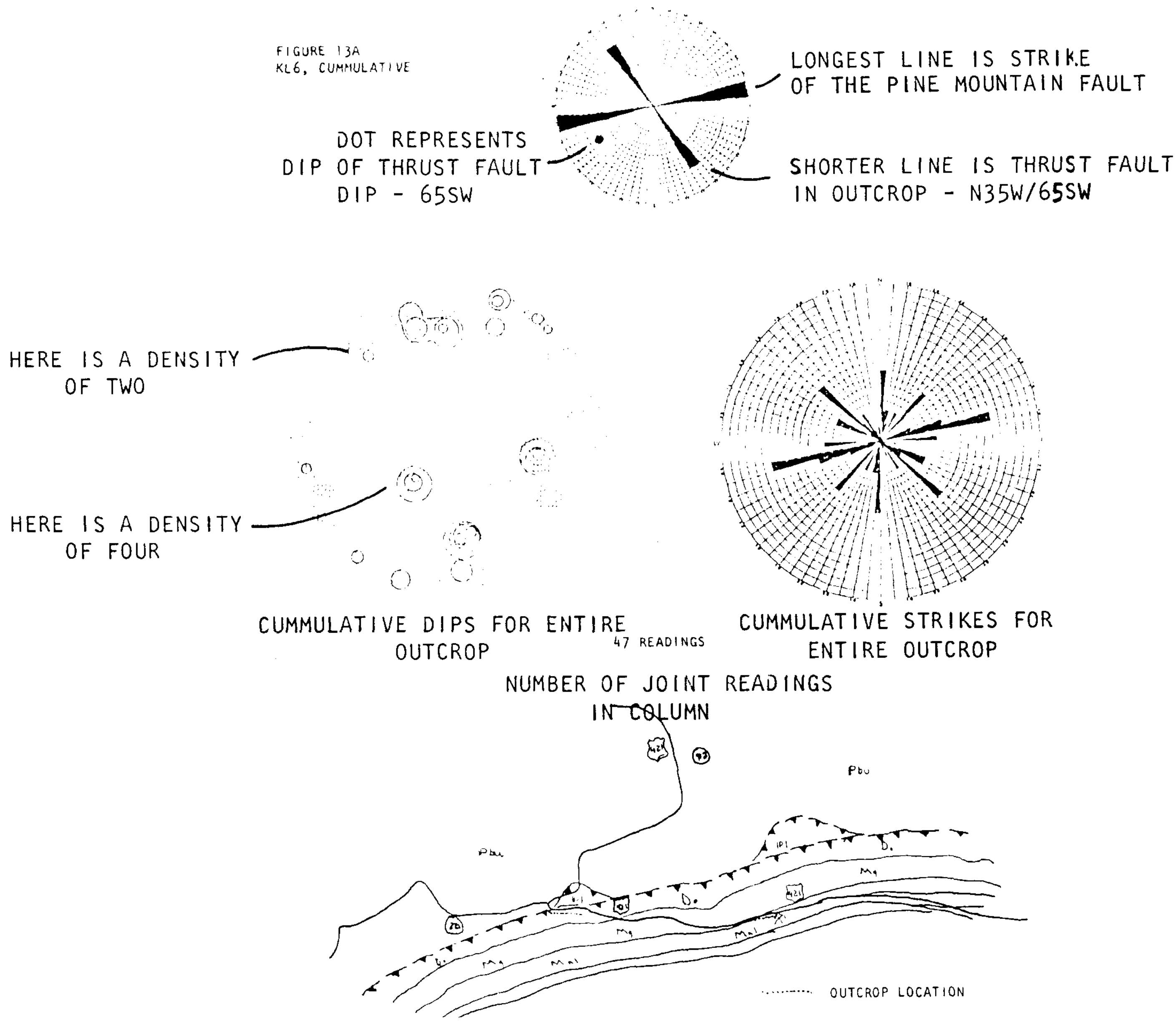


FIGURE 6
KEY TO COLUMN CUMULATIVE DATA -
GUIDE TO INTERPRETATION

ELKHORN CITY QUAD
ACCESS ROAD TO ELKHORN
CITY GRAVEL CO.

KL1

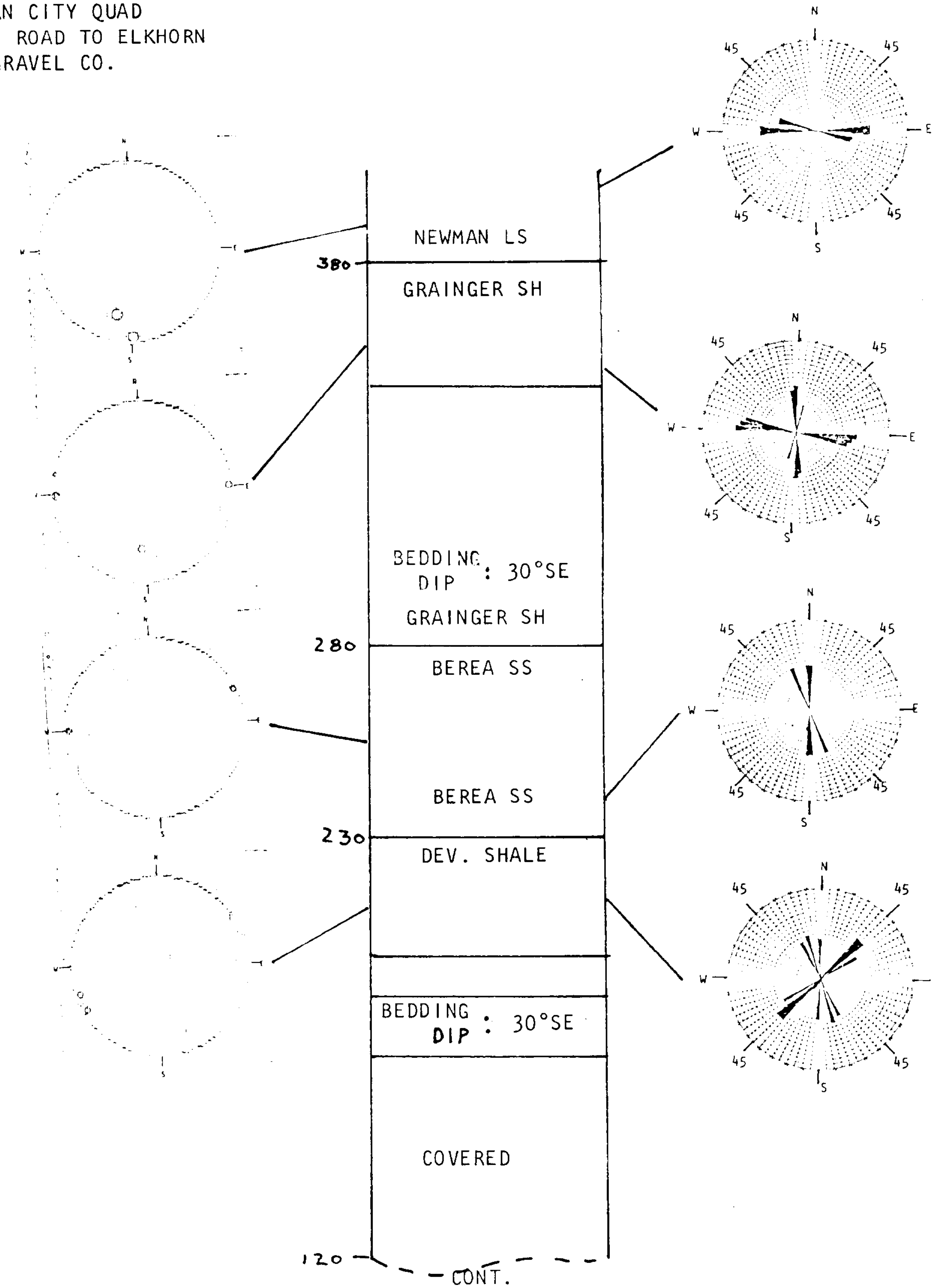


FIGURE 7

ELKHORN CITY QUAD
CONT.

KL1

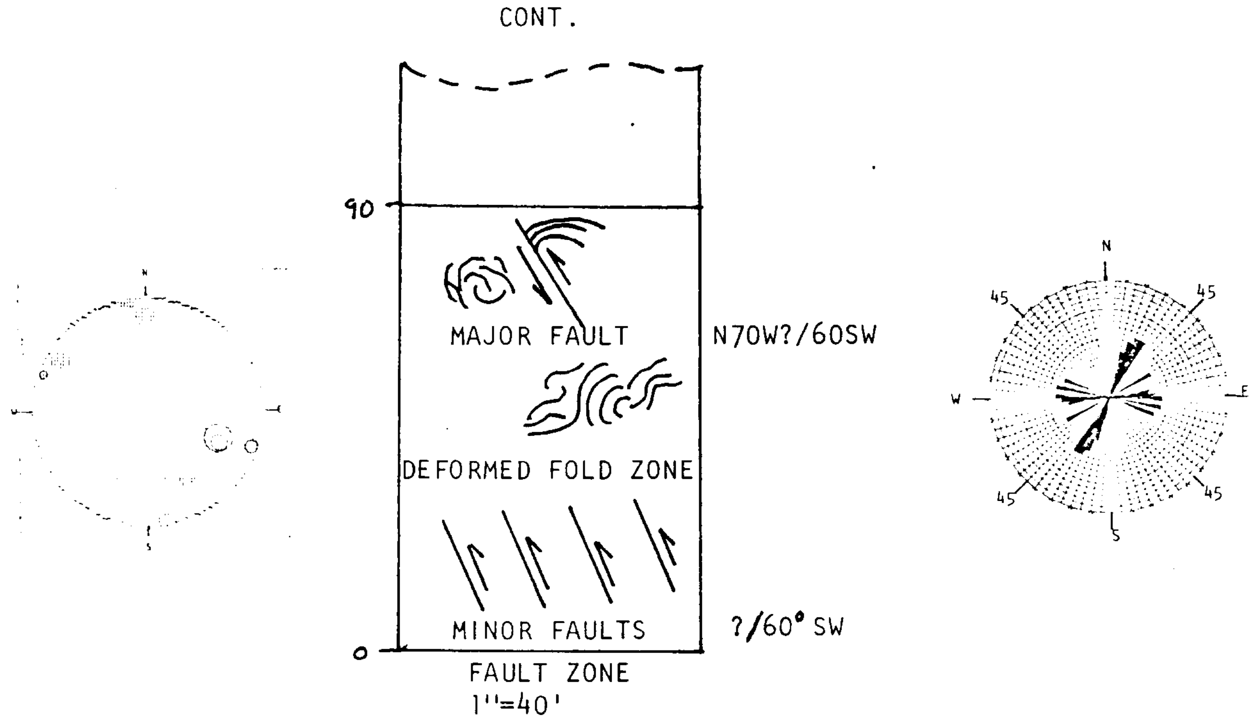
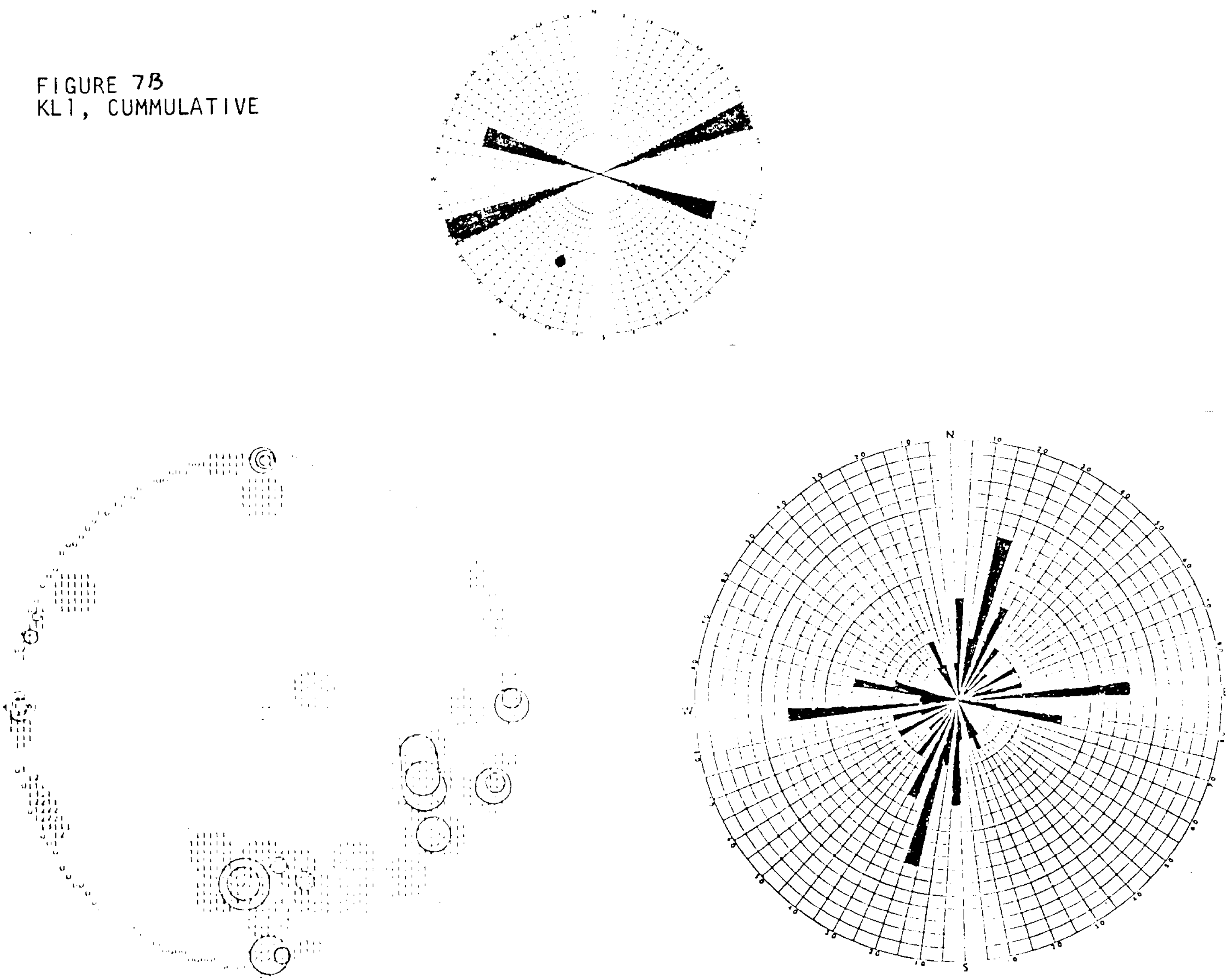
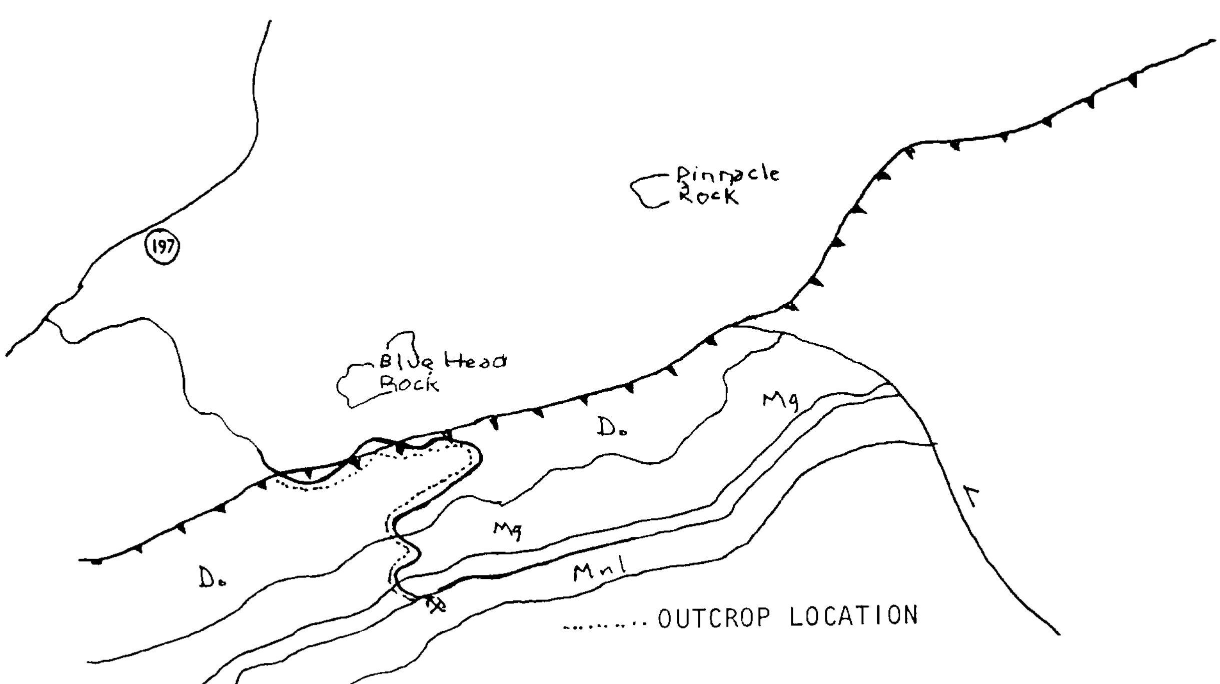


FIGURE 7A

FIGURE 7B
KL1, CUMMULATIVE



34READINGS



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HELLIER QUAD
ACCESS ROAD TO JOHNSON
BROS. LS QUARRY
SECTION 10 IN THREE
LICK BED: GUIDE BOOK

KL2

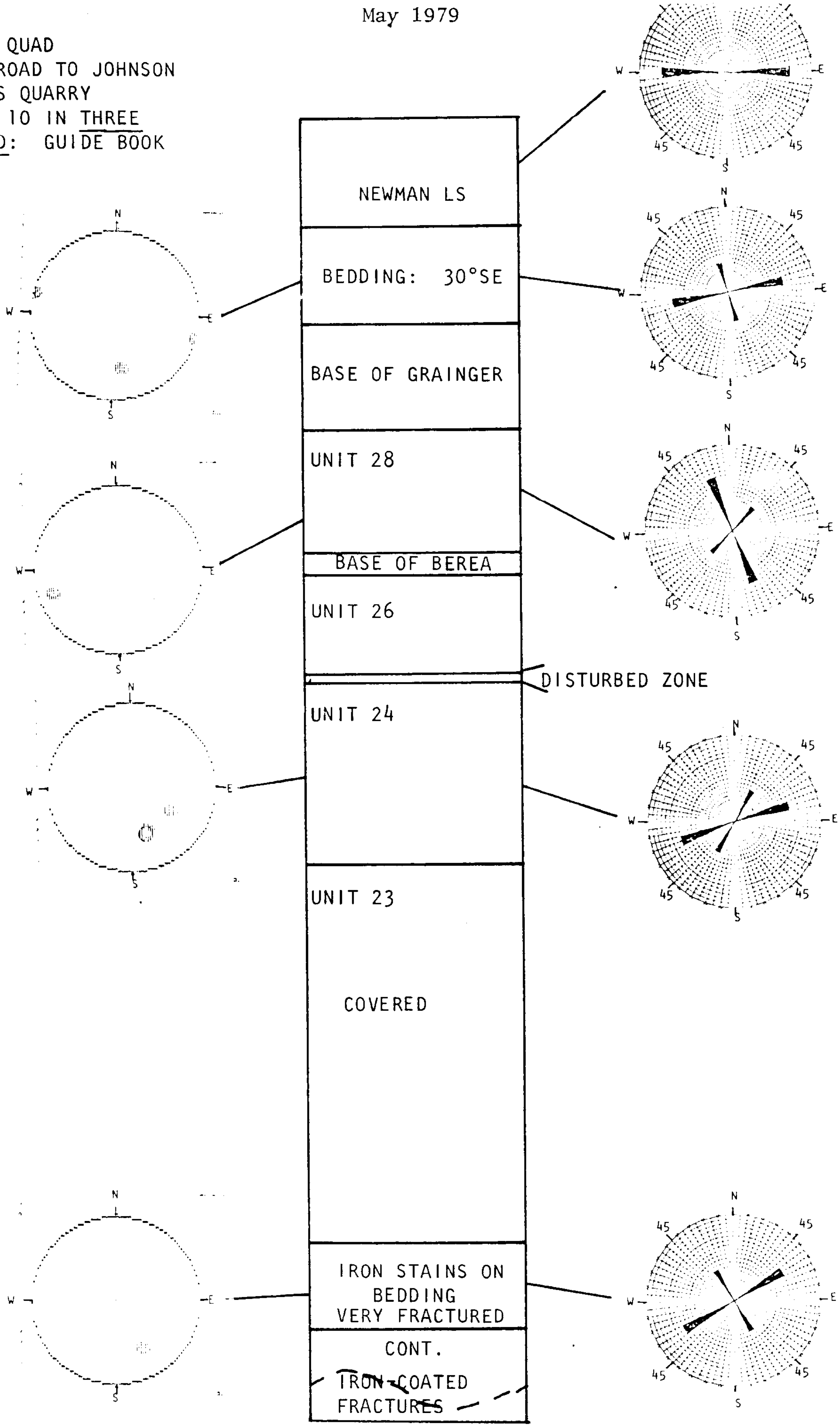


FIGURE 8

HELLIER QUAD
CONT.

KL2

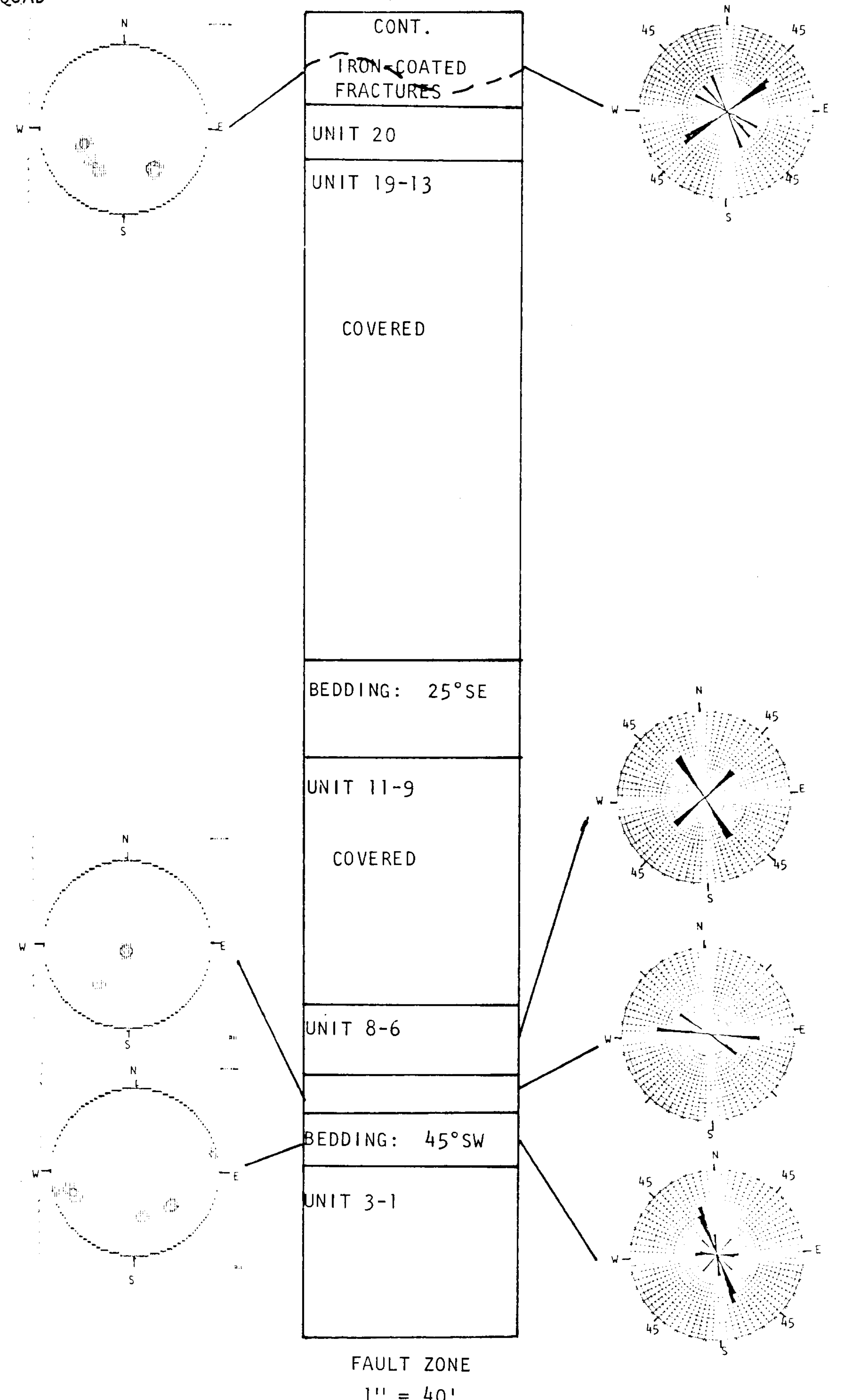
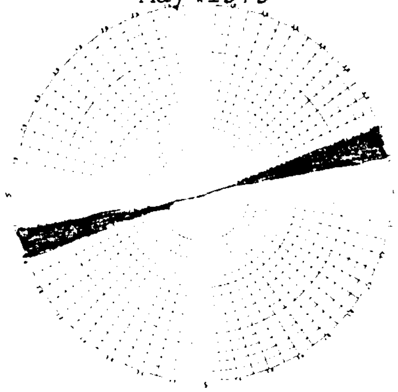
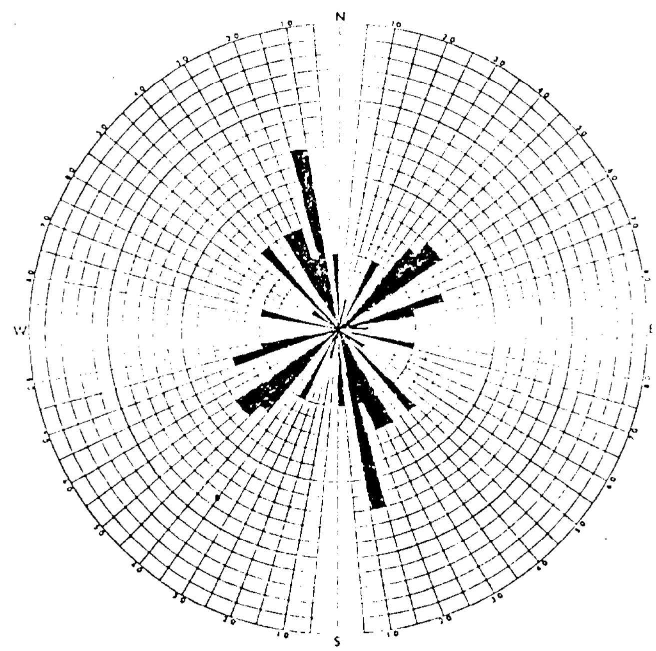
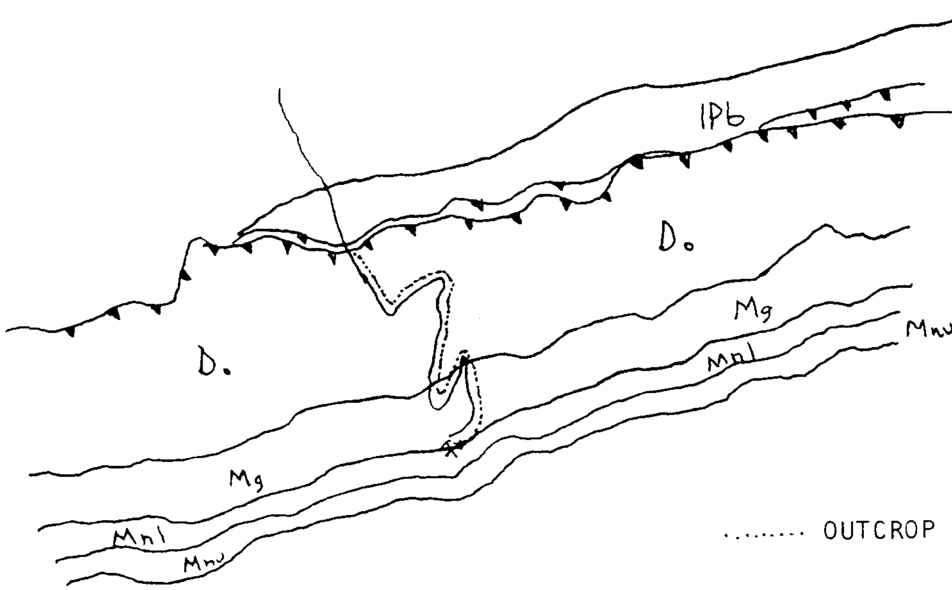


FIGURE 8A





26 READINGS



.... OUTCROP LOCATION

FIGURE 8B
KL2, CUMMULATIVE

JENKINS EAST QUAD
ACCESS ROAD TO ADAMS STONE
CORP. LS QUARRY

KL3

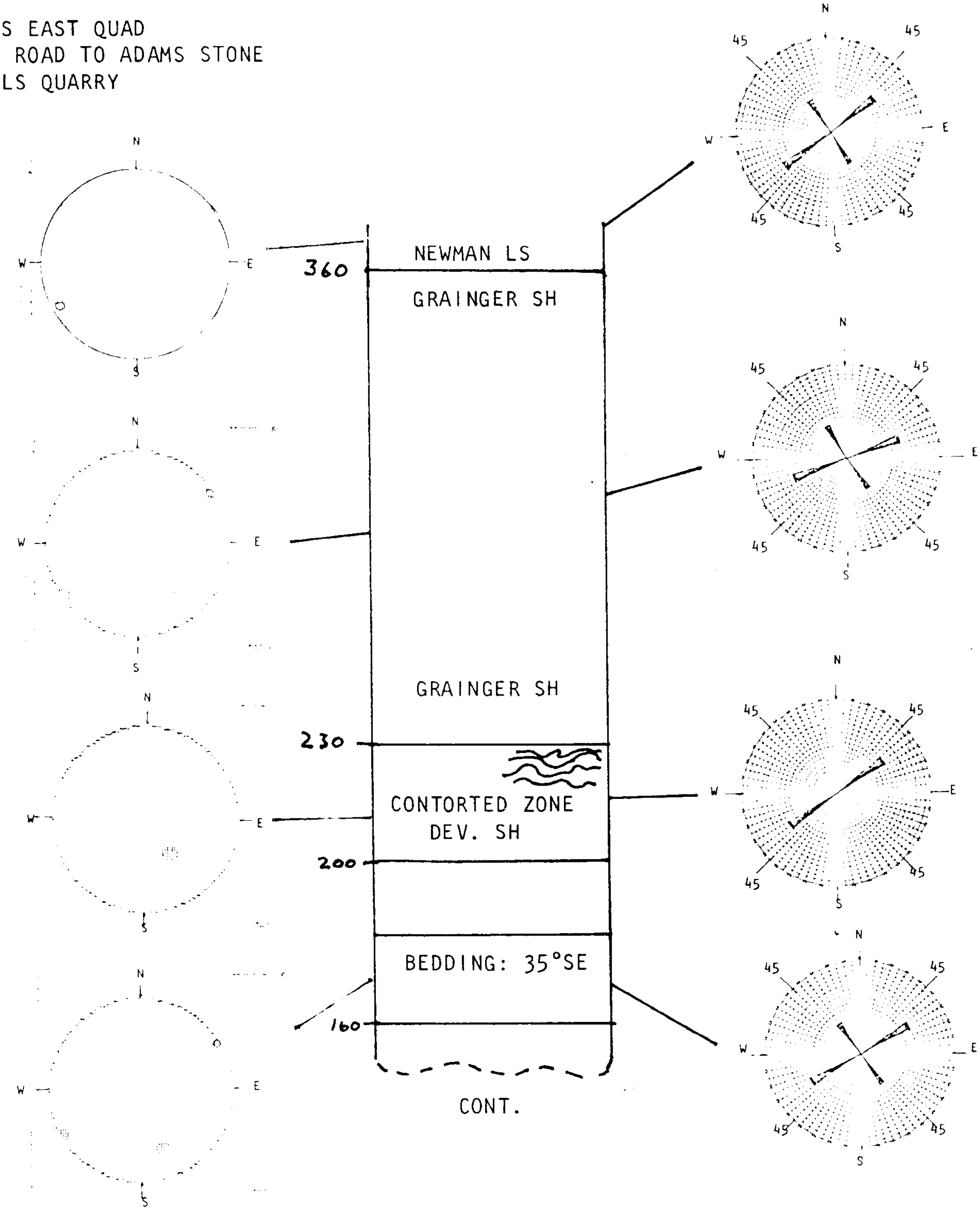


FIGURE 9

JENKINS EAST QUAD
CONT.

KL3

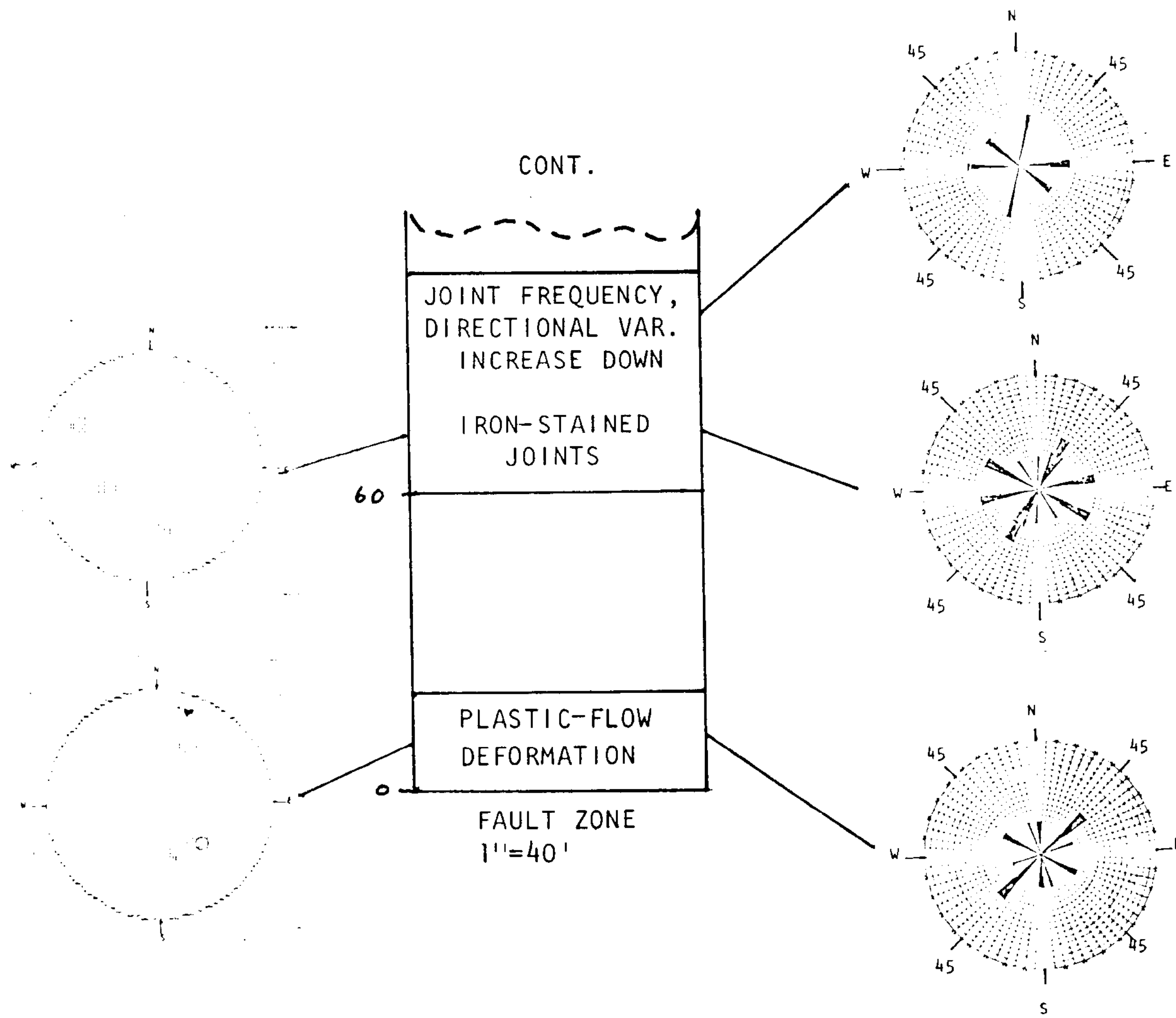


FIGURE 9A

FIGURE 9B
KL3, CUMMULATIVE

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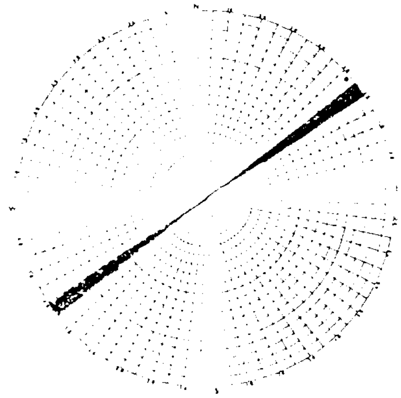

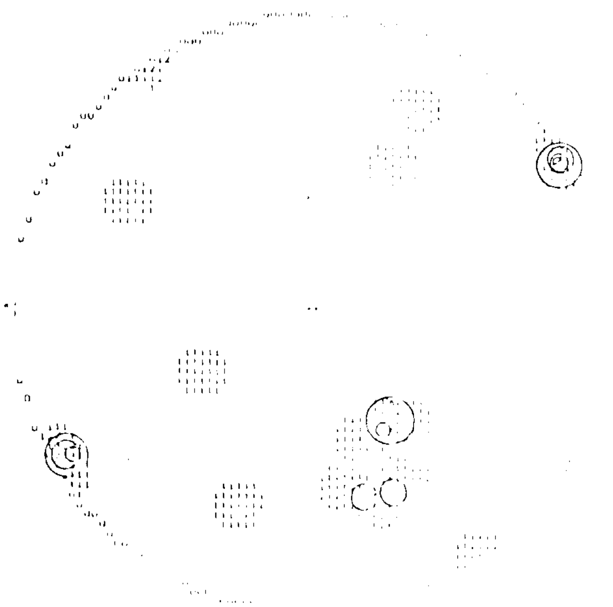

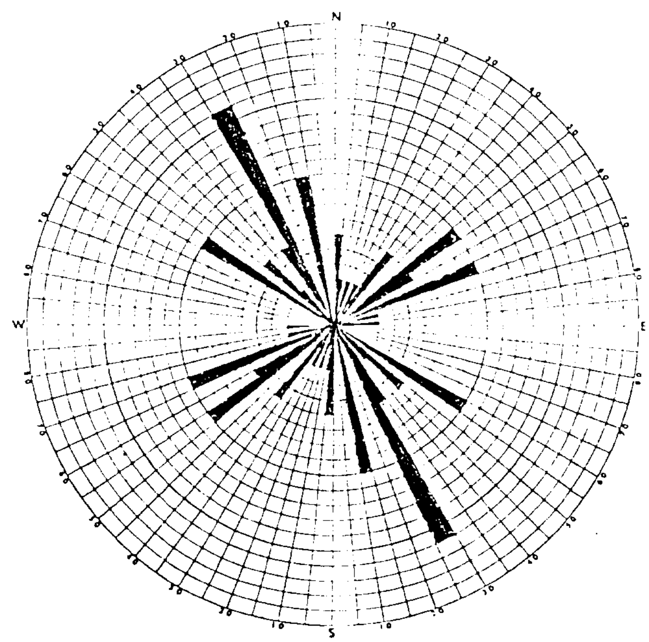

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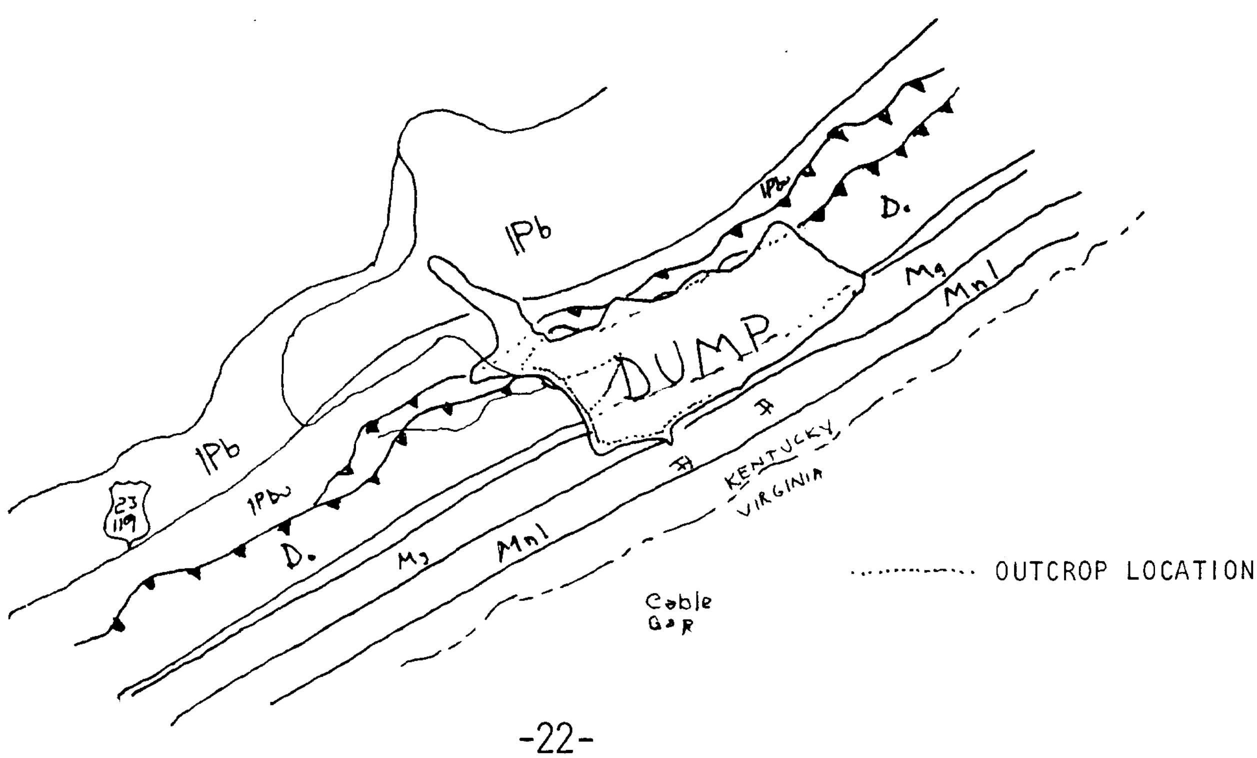


JENKINS WEST QUAD
RTS. 23 and 119, ABOUT
1 MILE SOUTH OF JENKINS

KL4

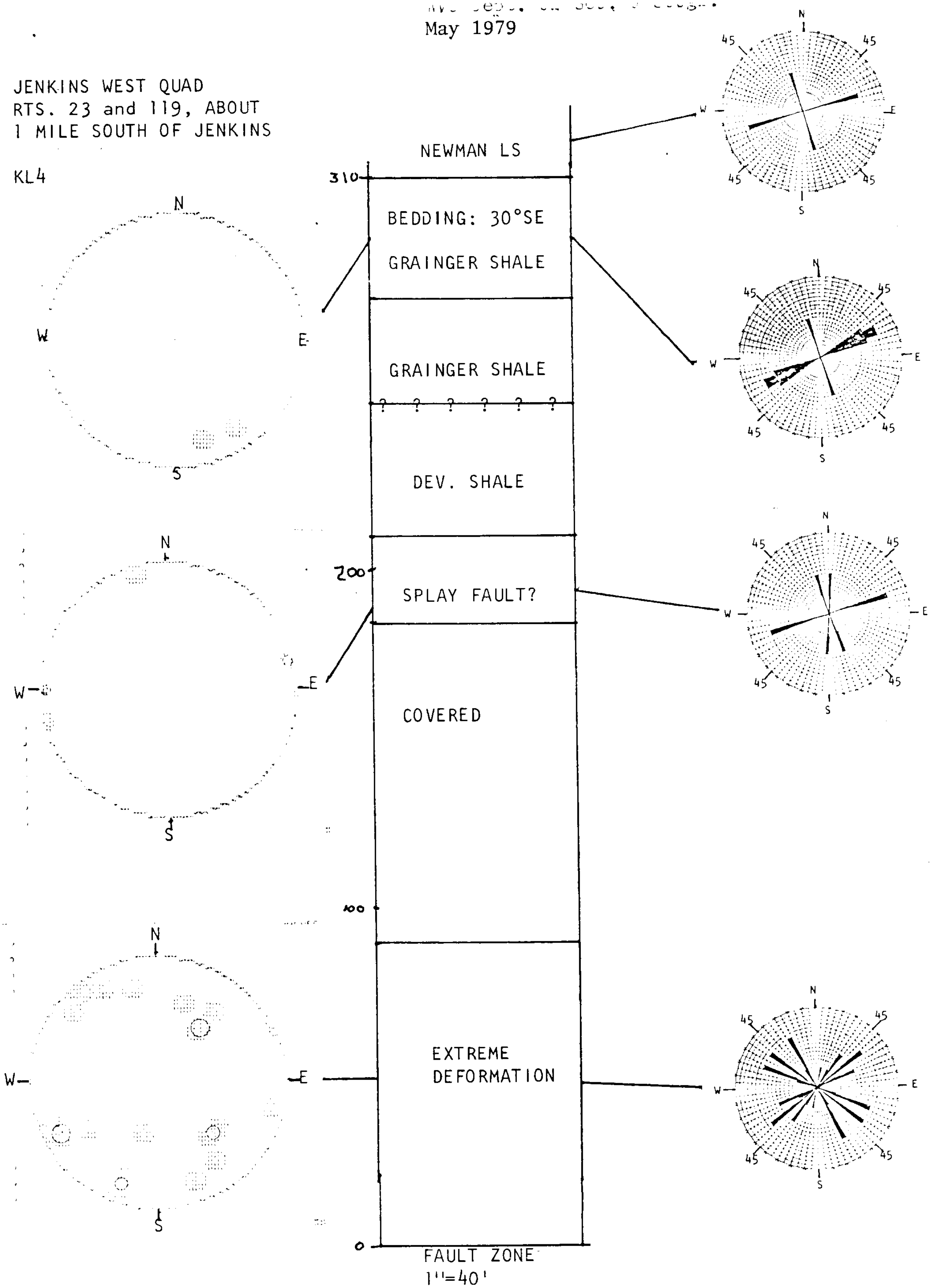
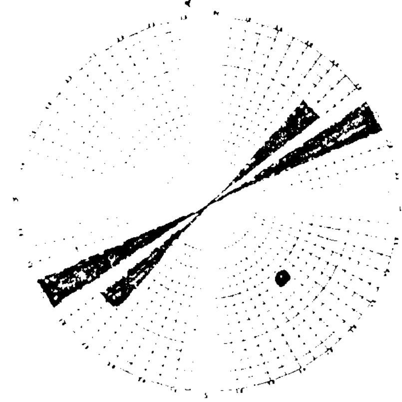
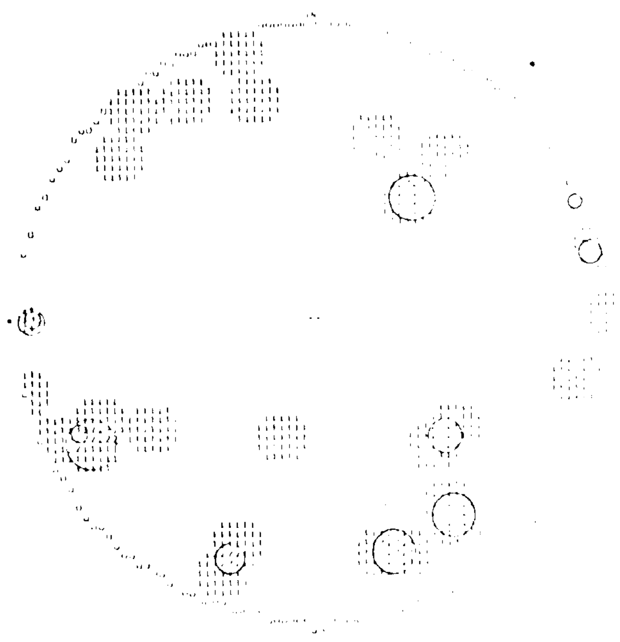
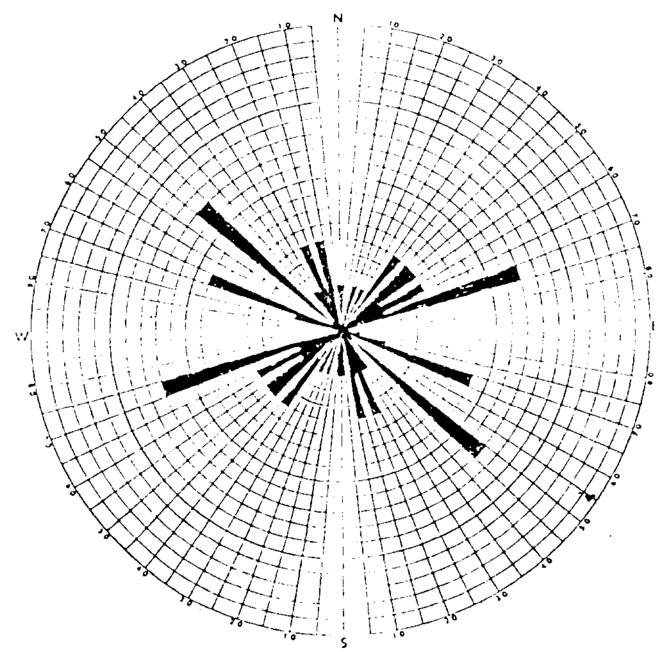


FIGURE 10







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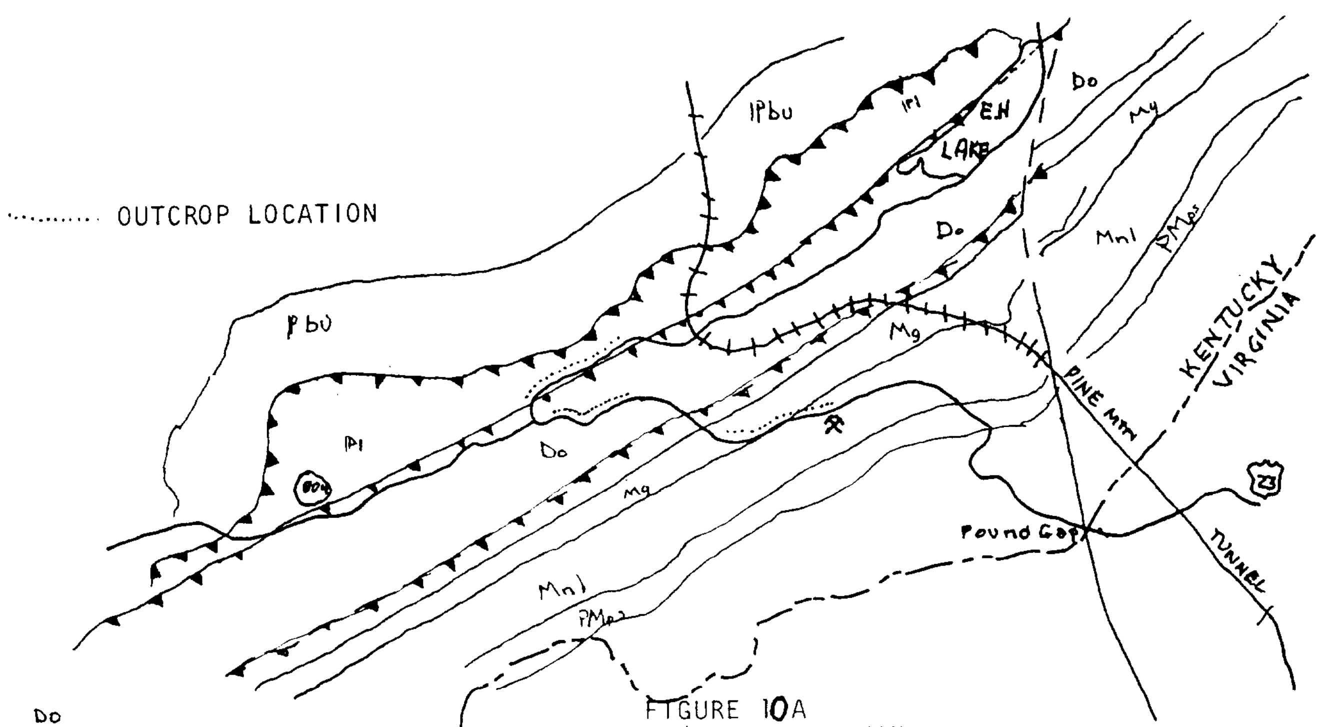


Do

FIGURE 10A
KL4, CUMMULATIVE

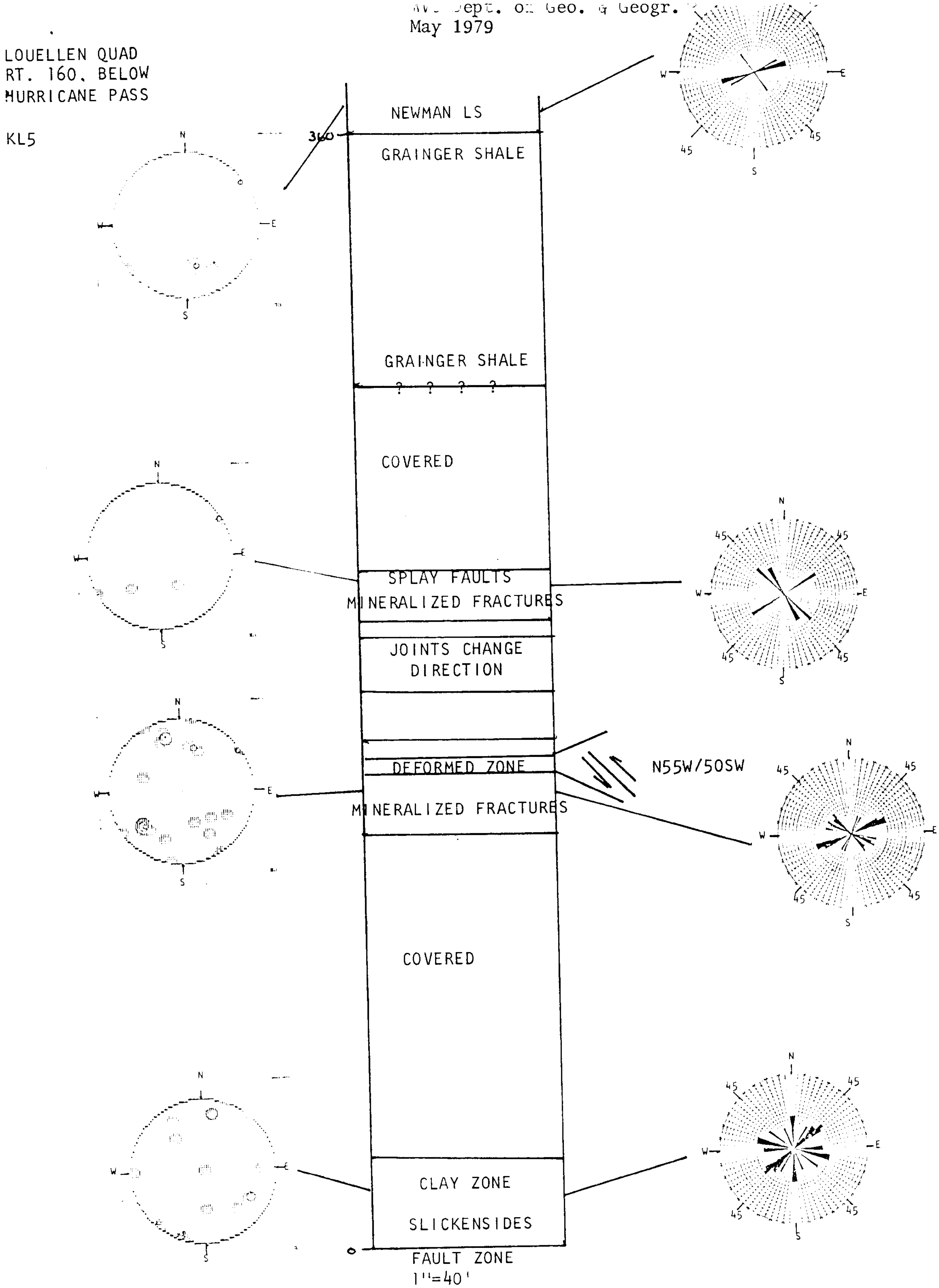
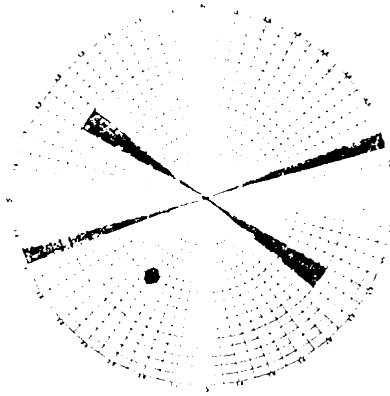
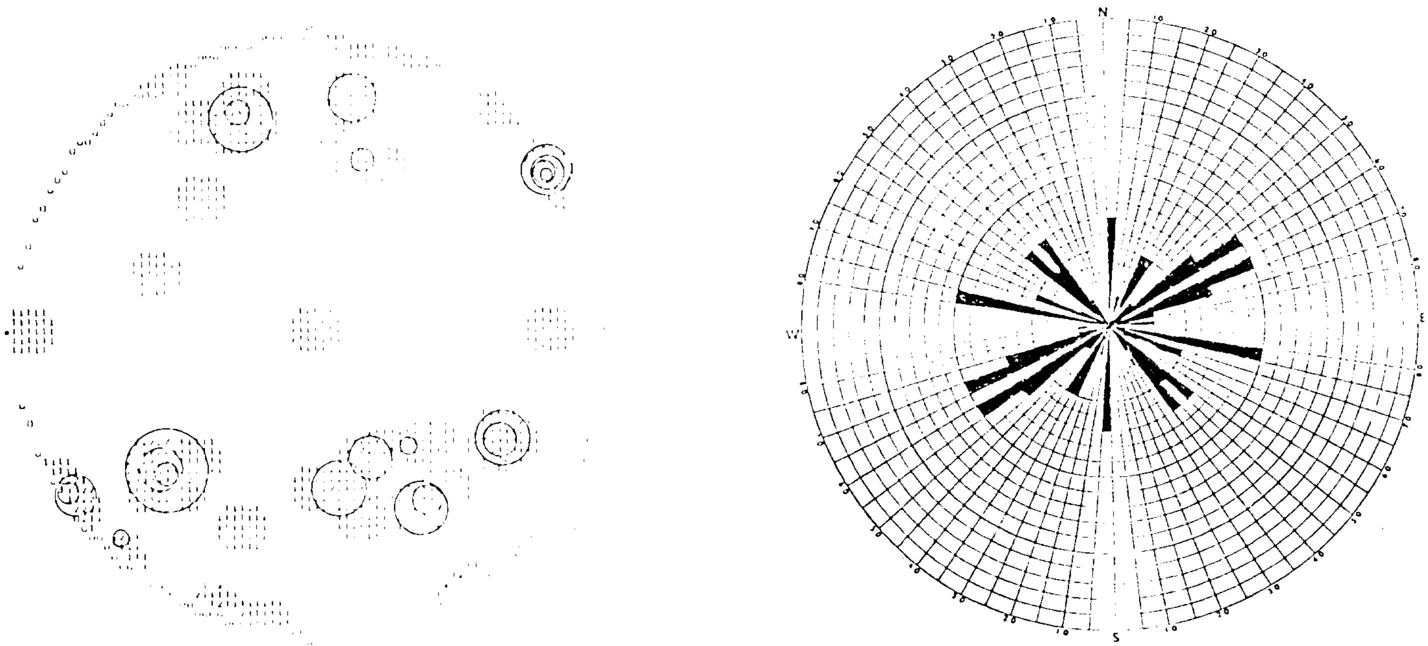
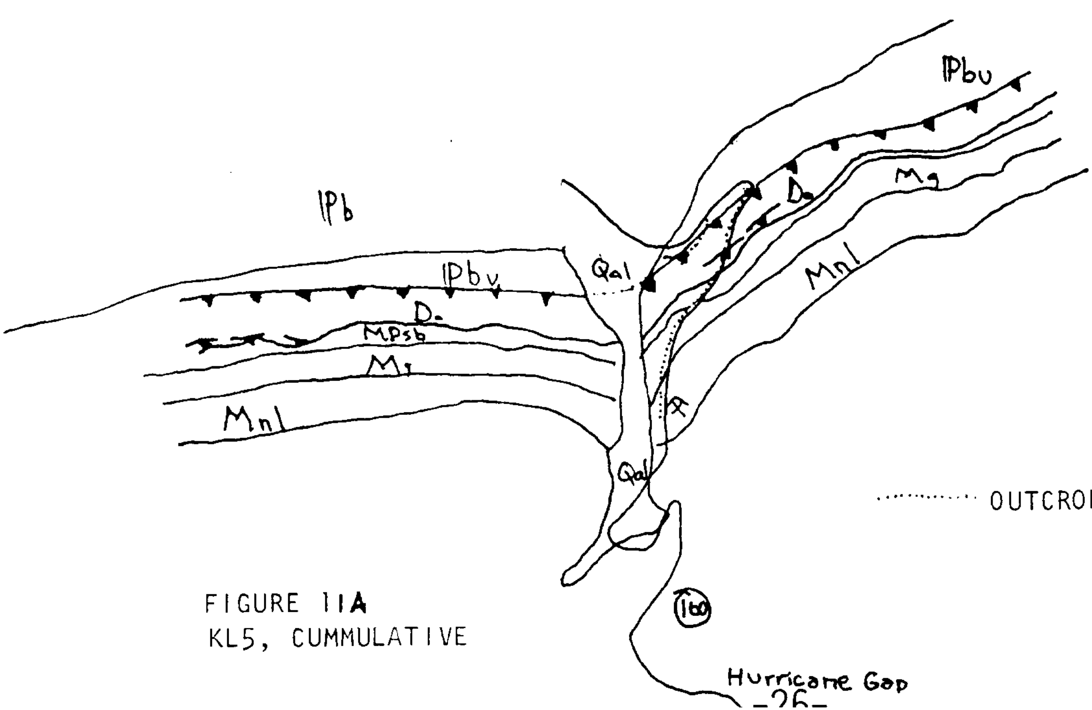

LOUELLEN QUAD
RT. 160, BELOW
HURRICANE PASS
KL5
NEWMAN LS
360
GRAINGER SHALE
GRAINGER SHALE
? ? ? ?
COVERED
SPLAY FAULTS
MINERALIZED FRACTURES
JOINTS CHANGE
DIRECTION
DEFORMED ZONE
MINERALIZED FRACTURES
N55W/50SW
COVERED
CLAY ZONE
SLICKENSIDES
0
FAULT ZONE
1''=40'
N
S
E
W
45

FIGURE 11





38 READINGS



········· OUTCROP LOCATION

FIGURE 11A
KL5, CUMMULATIVE

BLEDSOE QUAD
RT. 421

KL6

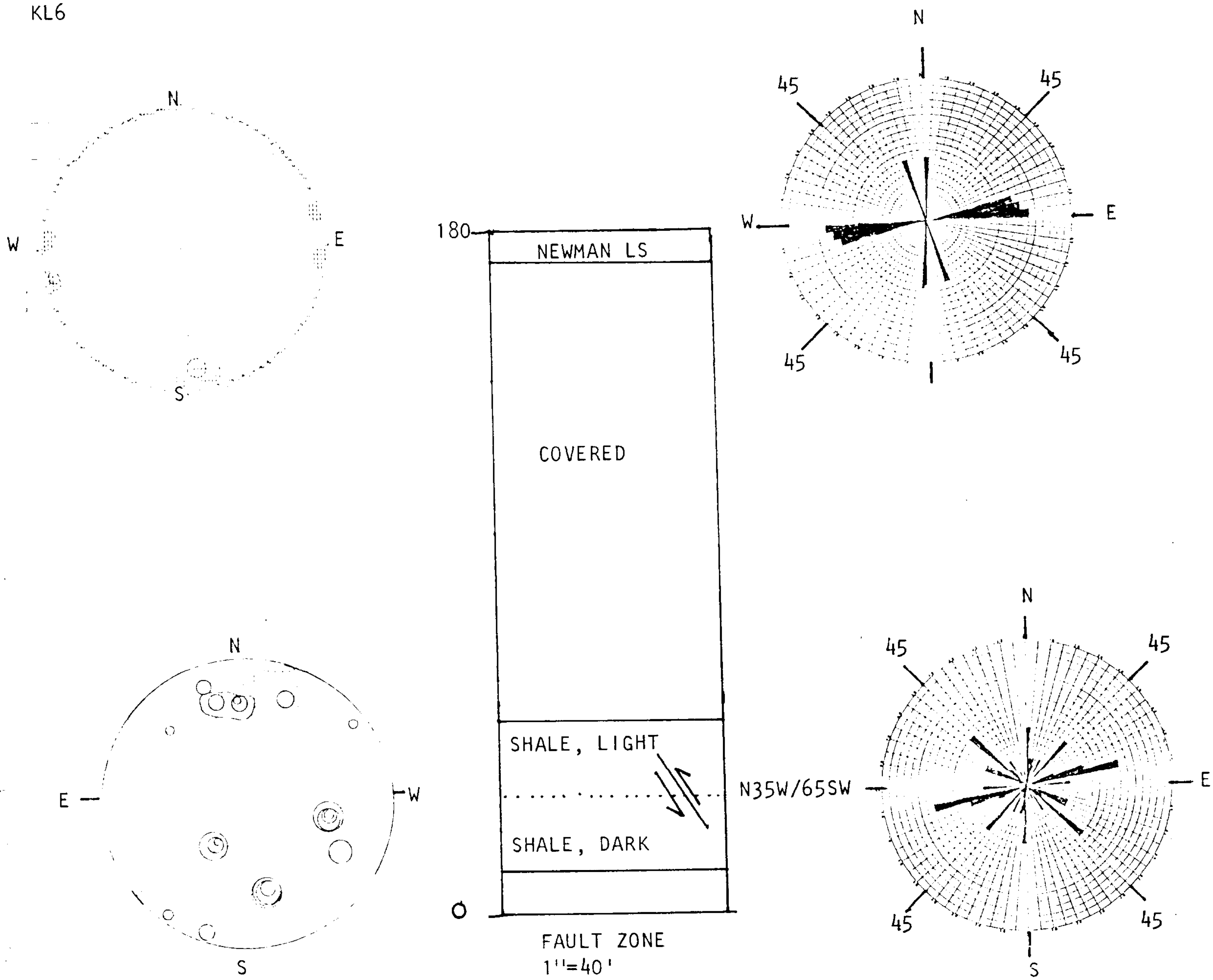
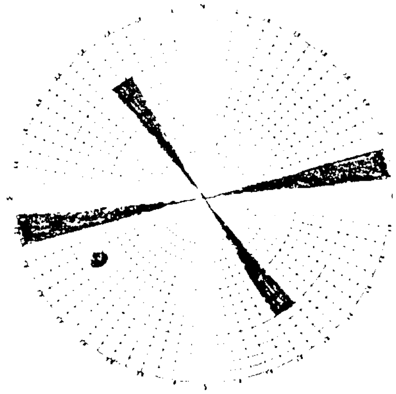
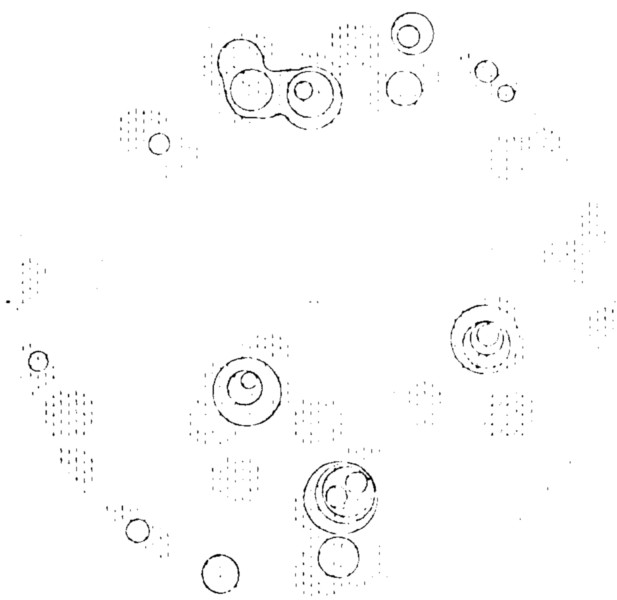
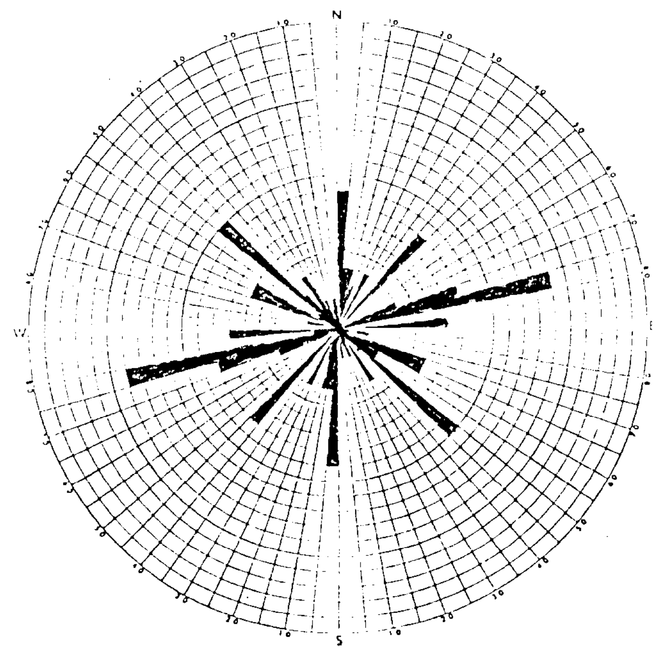


FIGURE 12

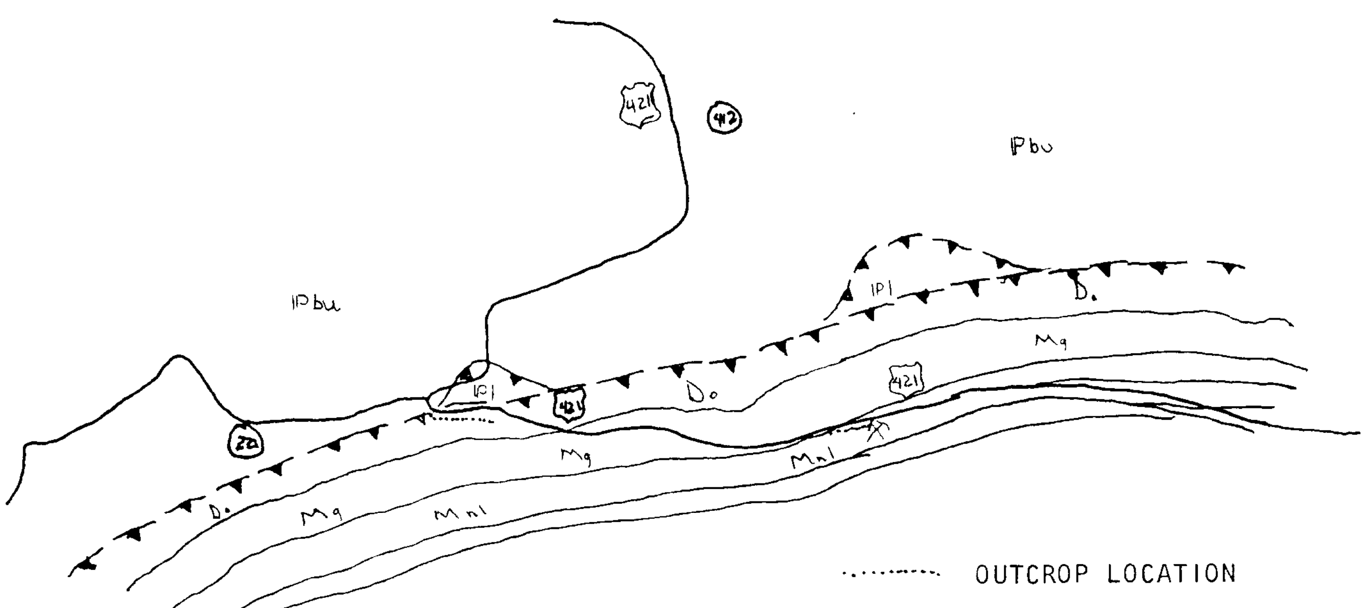
FIGURE 12A
KL6, CUMMULATIVE







47 READINGS



	CLOSE TO PINCHOUT OF SHALE ALONG STRIKE	SPLAY FAULTS ON OUTCROP SCALE	THRUST FAULTS ON OUTCROP SCALE	RANDOM FRACTURES	FLOW CHARACTERISTICS		JOINT DENSITY INCREASES DOWN	JOINTS CHANGE DIRECTION DOWN
					AT TOP OF SHALE	AT BOTTOM OF SHALE		
JOHNSON BROS. QUARRY **KL 2** ROAD	NO	NO	NO	YES	YES	NO	?	YES
JENKINS EAST QUARRY **KL 3** ROAD	NO	?	?	YES	YES	YES	YES	YES
JENKINS WEST **KL 4** ROADCUT	YES	YES	YES	YES	?	YES	?	?
HURRICANE PASS **KL 5**	NO	YES	YES	YES	?	YES	?	YES
BLEDSOE CHURCH **KL 6**	NO	?	YES	YES	?	?	?	?
ELKHORN QUARRY ROAD **KL1**	YES	NO	YES	YES	NO	YES	YES	YES

FIGURE 13
CHART OF STRUCTURAL FEATURES

Conclusions

1) Jointing in the Newman Limestone consists of a dominate strike set parallel to the Pine Mountain thrust, and a dip set perpendicular to the thrust front.

2) Jointing in the underlying Grainger shales and Berea sandstone are similar to jointing in the limestone, but can show slight rotation of joint strike, and greater variability in the strike of joint directions, especially in the second, or dip set.

3) A Narrow zone of deformation may be present near the top of the Devonian shales. This zone may reflect flexurial flow as the stiffer units above glided over the weaker shales during formation of the main Pine Mountain thrust, found at the base of the shale.

4) The number of joint sets throughout an outcrop increase with depth, or, the closer to the fault zone, the greater the trend and number of joint sets. Shumaker (1976) noted anamolous dip readings in the dip meters of the No. 1 Combs well in the Big Sandy field (perhaps reflecting mineralized fractures) in organic zones near the base of the shale and near the top of the shale. The two zones also contain slickensides indicative of movement (Shumaker, 1976). In addition Ray (1967) reports two main zones of production from these same organic layers. (See Figure 14) It seems possible that the two deformed zones at Pine Mountain correlate with those discussed by Shumaker (1978) and Ray (1967).

5) The strikes of joint sets at the top of the Devonian shales do not match the strikes of joint sets at the bottom of the Devonian shales. Somewhere between the top and bottom of the Devonian shales is a zone, sometimes narrow, where the joints change strike. This is graphically illustrated on KL3 between elev. 80 and 160, and was seen on one outcrop

FRACTURED DEVONIAN SHALE WELLS
PERRY COUNTY, KY.

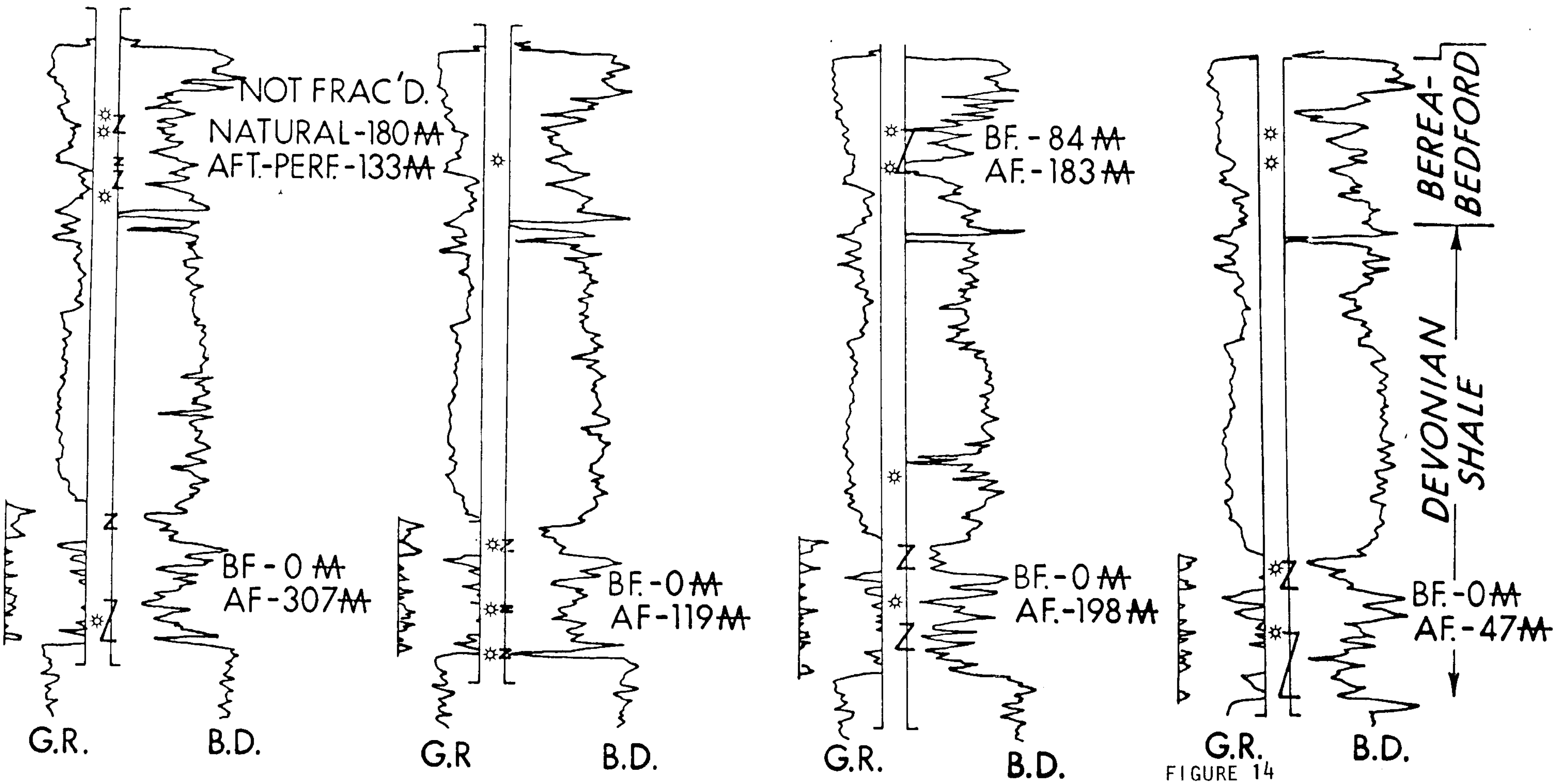


FIGURE 14
PRODUCTIVE ZONES IN DEVONIAN SHALE

RAY-1967

on KL5.

6) The most deformed zones occur in the lower part of the Devonian shales near to the disappearance of the shales along strike of the Pine Mountain thrust, and conversely as the shale thickens above the thrust there is a greater section of undeformed shale.

7) Thrust faults in the Devonian shale, as seen in outcrop, are not parallel to the main Pine Mountain fault. Thrust faults in the shale that are parallel to the main thrust may be obscured on bedding planes. A clay rich zone at the bottom of KL5 may be one such fault.

8) Random fractures, or non-systematic fractures throughout entire outcrops, were noted in some exposures at every column studied. These could be related to blasting, weathering, or tectonic deformation.

9) Each column usually has joint sets sub-parallel and sub-perpendicular to the Pine Mountain thrust.

10) Where thrust faults are detectable in outcrop, the strikes consistantly correspond to strikes of a joint pattern. However, the dips of the thrust faults do not consistantly correspond to dips of a joint pattern.

Harris, L.D., 1970, Details of thin-skinned tectonics in parts of Valley and Ridge and Cumberland Plateau provinces of the southern Appalachians, in Fisher, G. W., and others, eds., Studies of Appalichian Geology-central and Southern: New York, Interscience Publishers, p. 161-173.

Harris, L. D. and Milici, R.C., 1977, Characteristics of Thin-Skinned Style of Deformation in the Southern Appalachians, and Potential Hydrocarbon Traps: Geol. Surv. Professional Paper 1018, 40p.

Provo. L.J., Kepferle, R. C., and Potter, P.E., 1977, "Three Lick Bed: Useful Stratigraphic Marker in Upper Devonian Shale in Eastern Kentucky and Adjacent Areas of Ohio, West Virginia, and Tennessee." MERC/CR-77/2, 56p.

Ray, Edward O., 1967, Reference Location Unknown

Ray, Edward O., 1976, Devonian Shale Development in Eastern Kentucky in Natural Gas From Unconventional Geologic Sources; National Academy of Sciences, Washington, D. C.

Rich, J.K., 1934, Mechanics of low-angle overthrust faulting as illustrated by Cumberland thrust block, Virginia, Kentucky, and Tennessee: Am. Assoc. Petroleum Geologists Bull., V. 18, No.12, p. 1584-1596.

Shumaker, Robert C., 1976, Kentucky, West Virginia Gas Company Final Report-Well No. 7239, Perry County, Kentucky: Text of U.S. Energy Research and Development Administration Contract No. E (46-1) 8000.

Shumaker, Robert C., 1978, Porous Fracture Facies in the Devonian shales of Eastern Kentucky and West Virginia: Geology Dept., West Virginia University.